" MICROWAVE HOLOGRAPHY OF DEEP SPACE NETWORK REFLECTOR ANTENNAS

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ABSTRACT

The microwave antenna holography imaging technique has progressed considerably in recent years. This technique has been successfully used for the diagnosis, analysis, and performance improvement of most of the National Aeronautics and Space Administration (NASA)/Jet Propulsion Laboratory (JPL) Deep Space Network (DSN) large reflector antennas, especially at the shorter wavelengths, The JPL Microwave Antenna Holography System (MAHST) enables high resolution and high precision antenna imaging with a standard deviation of 100 microns. Panel setting/unbending screw adjustment is provided to an accuracy of 10-20 microns. In May of 1994, the MAHST was applied to the newly constructed 34-meter beamwaveguide (BWG) antenna (11 SS-24) in Goldstone, California. The application of the MAHST provided the critical RF performance necessary to meet not only the project requirements and goals but to surpass them. A performance increase of 0.35 dB at X-band (8.45 GHz), and 4.9 dB at Ka-band (32 GHz) was achieved relative to the theodolite set surface, resulting in peak efficiencies of 75.25% at X-band and 60.6% at Ka-band from cassegrain focus F1 (reference to the input of the LNA). The main reflector was set in one application to 0.25-mm rms, making DSS-24 the highest precision antenna in the NASA JPL-DSN. The precision of the 11 SS-24 antenna (diameter/rms) is 1.36x 10^5, and its gain limit is at 95 GHz.

OVERVIEW

The holography technique has proven to be the least expensive method for increasing the link performance of the DSN ground antennas. The MAHST provides an efficient and low cost technique to optimize and maintain the performance of large Earth-station antennas, helping to fulfill today's requirements for ever increasing link performance. The MAHST samples the far-field amplitude and phase pattern of the antenna under test with a 90-dB dynamic range. A fast subreflector position optimization is provided which further increases the antenna performance. Outputs of the system include aperture amplitude and phase functions, gravity deformation characterization and analysis, as well as directivity computations at other frequencies. The JPL MAHST is a portable system that can be shipped to any DSN antenna in the world and easily interfaced with its encoders and antenna drive systems. The MAHST was designed utilizing many "off the shelf" commercially available components. The remaining parts were designed and built at JPL. The MAHST has been successfully tested and demonstrated in the NASA/JPL-DSN (Figure 1).

The holographic metrology technique utilizes the Fourier Transform relationship between the complex far-field radiation pattern of an antenna and its complex aperture distribution. The resulting aperture phase and amplitude distribution information is used to precisely characterize various crucial performance parameters, including panel alignment, subreflector position, antenna aperture illumination, directivity at various frequencies, and gravity deformation effects. Application of the MAHST information provides improved performance to the antenna that increases its signal-to-noise ratio (SNR) and therefore its channel capacity or information processing rate. Strong Continuous Wave (CW) signals obtained from geostationary satellite beacons are utilized as far-field sources. These strong CW beacon signals are available on many satellites at Ku-band and X-band. A portable 2.8-meter antenna is used on the reference channel to provide the phase reference signal to the receiver phase-lock-loop (PLL). The IF section consists of a Hewlett Packard Microwave Receiver (HP8530A) and an external PLL that enables amplitude and phase measurements of the ground antenna sidelobes with a 90-dB dynamic range. The far-field data is collected by continuously scanning, on a two-dimensional grid, the antenna being measured against a signal from a geosynchronous satellite. The angular extent of the data required is inversely proportional to the size of the desired resolution cell in the processed holographic maps and to the measurement frequency. The information in the surface error map is then used to compute the adjustments of the individual panels in an overall main reflector best-fit reference frame. The amplitude map provides valuable information about the energy distribution in the antenna aperture.

ACCOMPLISHMENTS

(1) The MAHST was used to set the newly built DSS-24 34-meter BWG antenna to 0.25 mm (infinite resolution axial error), making it the highest precision instrument in the NASA/J PL-DSN. The precision

of DSS-24, 1.36x 10^5 (diameter/rms), was achieved with a single iteration of panel setting. By setting the panels and correcting the subreflector position, the MAHST improved the performance of DSS-24 by 4.9 dB at Ka-band and 0.35 dB at X-band relative to its initial theodolite condition (Table 1). The achieved peak efficiency of 11 SS-24 at 45-degrees elevation is 60.6% at Ka-band referenced to the input of the LNA (Table 2).

(2) Microwave holography application to antenna gravity deformation:

(a) The information obtained by the MAHST was utilized for designing, fabricating and calibrating a prototype deformable flat-plate that compensates for the gravity deformation of a 34-meter BWG antenna (Ref. 3). The resulting improvement at 12.7-degrees elevation is 1.73 dB at Ka-band (Table 3).

(b) Gravity deformation characterization by holography led to an improved gravity deformation design of future DSN BWG antennas.

(c) A low cost device - cammatic actuators - suggested by Dr. Roy Levy of JPL has resulted in significant gravity performance improvement of the DSS-13 34-meter BWG antenna. An improvement of 1.14 dB at Ka-band was inferred from holographic measurements at 12.7-degrees elevation (Table 3).

(3) The MAHST was used to set and unbend the panels of DSS-13. First, panel setting was utilized to improve the antenna rms surface from 0.88 mm to 0.38 mm. Then, panel unbending was utilized to further improve its rtns surface error from 0.38 mm to 0.31 mm. Since DSS-13 was commissioned in 1990, microwave holography has improved its performance by 5.25 dB at Ka-band. Microwave holography has enabled radio science observations to 49 GHz at 1)SS-13.

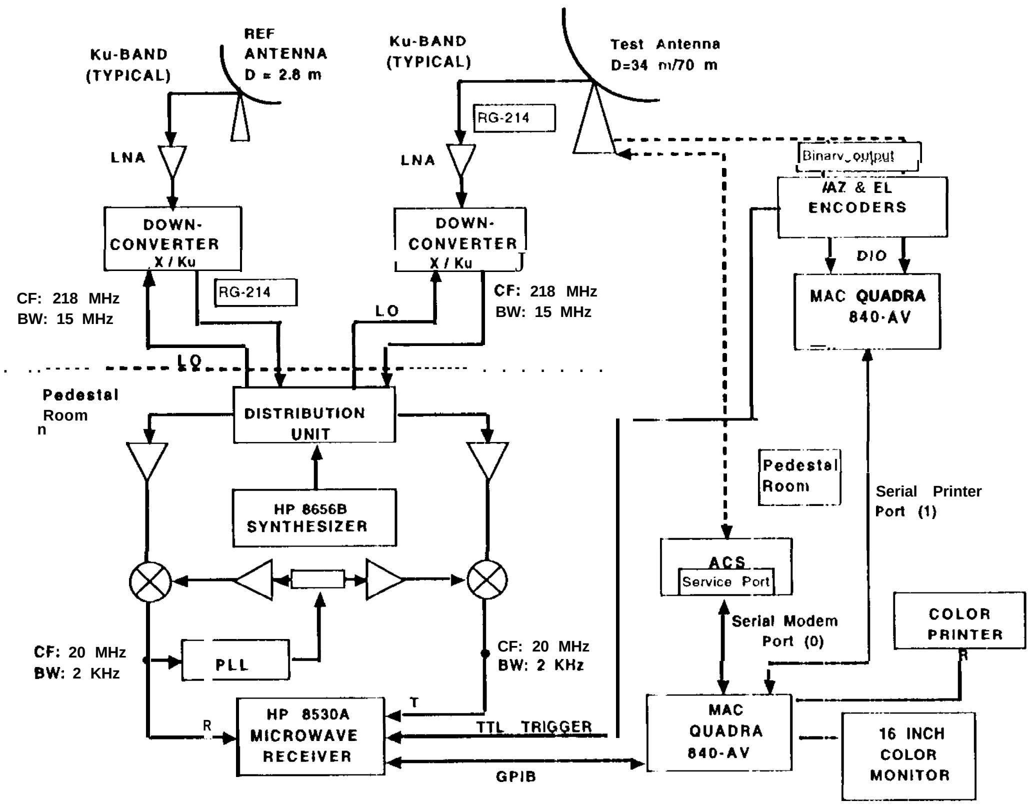

Figure 1. Microwave Antenna Holography System (MAHST) Block Diagram

TABLE 1.
DSS-24 34-meter BWG Antenna Performance Improvement (dII) by Microwave Holography al 45-deg. Elevation

Frequency	Panel Setting (dB)	Subreflector (dB)	Total (dB)
X-band (8.45 GHz)	0.1	0.2s	0.35
Ka-band (32 GHz)	1.27	3.6	4.87

TABLE 2.
DSS-24 Aperture Efficiency (%) at 45-deg. Elevation*

Value/Frequency	X-band (8.45 GHz)		Ka-band (32 GHz)	
Focus	F1	F3	F1	F3
Expected	78.9+ /-1.5	77.6+/-2.5	68.2+/-3.0	59.9+ /-4.0
Specified	N/A	72.0	N/A	41.0
As Built	71.2+/-3.0	68.83 3+/-3.0	21.07 +/-4.0	19.83 +/-4.0
Measured Post Holography	77.25 +/-2.0	74,61 +/-2.0	65.14+/-2.3	61.29+/-2.7

* It fficiency is referenced to horn aperture

TABLE 3.
1) SS-13 34-meter BWG R&D Antenna Computed Ka-Band Performance Improvement 12.7-deg. Elevation

Subreflector	Flat-Plate	Cammatic
0.6 dB	1.73 dB	1.14 dB

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